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ON THE PACIFIC SARDINE (*SARDINOPS CAERULEA* GIRARD) IN AQUARIA: TRANSPORTATION, HANDLING, MAINTENANCE, AND SURVIVAL

BY

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Introduction

The behavior of marine fishes under laboratory conditions, particularly that of members of the Clupeoidea, has been very little studied. Parr (1927) offers this explanation: "It is most unfortunate that the species showing the schooling performances most clearly, as for instance herrings, spratts, and mackerels, usually are of such delicate nature that it is practically impossible to keep them alive for any length of time." Further reference to the subject is made by Spooner (1931) who states: "Choice of schooling fish suitable for observation in captivity is limited to a very few species. Small mackerel, herring, and spratt are excluded on account of difficulties involved in keeping them in confinement."

A number of behavior studies under laboratory and field conditions have been made, however, on various species of herrings (Newman, 1876; Shelford and Powers, 1915; Powers, 1921; Breder, 1929), and on several unrelated marine fishes, including the great blue shark *Prionace glauca* (Hubbs, 1948), and the tarpon *Tarpon atlanticus* (Shlaifer and Breder, 1940; Shlaifer, 1941).

Papers on the Pacific sardine *Sardinops caerulea* (Girard) have been confined largely to scattered field observations by Cornish (1883) and Allen (1920, 1930).

*Submitted February 10, 1953.

Fishes of the suborder Clupeoidea are anatomically, physiologically, and temperamentally among the most delicate of marine fishes. This is especially true of the Pacific sardine, whose nervous temperament, so familiar to men engaged in the sardine fishery, renders it a difficult subject for laboratory study. The ease with which the sardine is injured through handling, coupled with its sensitivity to environmental changes in salinity, temperature, and oxygen may well account for the absence of laboratory studies on this economically important fish.

Since these fishes rank among the most important from the standpoint of the world's economy and resources, it was deemed necessary to establish the conditions under which they should be transported to a laboratory and there maintained as objects for detailed experimental investigations.

Methods of Handling

Transportation:

Altogether, seven shipments of live adult sardines, totalling 751 specimens, were delivered to the Steinhart Aquarium during 1949–51. The first three lots, purchased from bait-fishermen, came from Monterey Bay.

The first lot of 57 sardines was delivered May 19, 1949. All the fish died off rapidly. The second lot of 37 sardines was delivered August 4, 1949. By the next day 27 fish (73 per cent) had died; the rest of the fish survived a few days. The third shipment of 24 sardines was made on December 22, 1949. Heavy casualties were incurred in the first 48 hours after delivery; however, five fish survived until the end of May, 1950.

This excessive mortality among the sardines from Monterey Bay was considered to be due to the long travel time (about three hours) in the collecting truck; so all subsequent collections were brought to San Francisco from the Los Angeles area aboard the M.S. *Yellowfin*, research vessel of the California Department of Fish and Game.

The sardines from the Los Angeles area were also purchased from bait-fishermen and were kept in the wooden bait-tank of the *Yellowfin*, which tank contained 1,125 gallons of circulating sea-water. The vessel's voyage between Los Angeles and San Francisco was usually made in 50–52 hours, and sometimes the ship experienced rough weather. Delivery to the Academy's Steinhart Aquarium from aboard ship, a distance of eight miles, was made in a collecting truck equipped with 45- and 100-gallon cans (fig. 1) that have air compressors and inside lights. Two or three truck trips, each of which took from 15 to 40 minutes, were required to unload each shipment. Dip-nets and two-gallon buckets were used for transferring the sardines, both at the dock and the Aquarium.

The fourth shipment of 128 sardines, from Long Beach, was delivered on June 9, 1950. In 96 hours after delivery, 85 sardines (66.5 per cent)

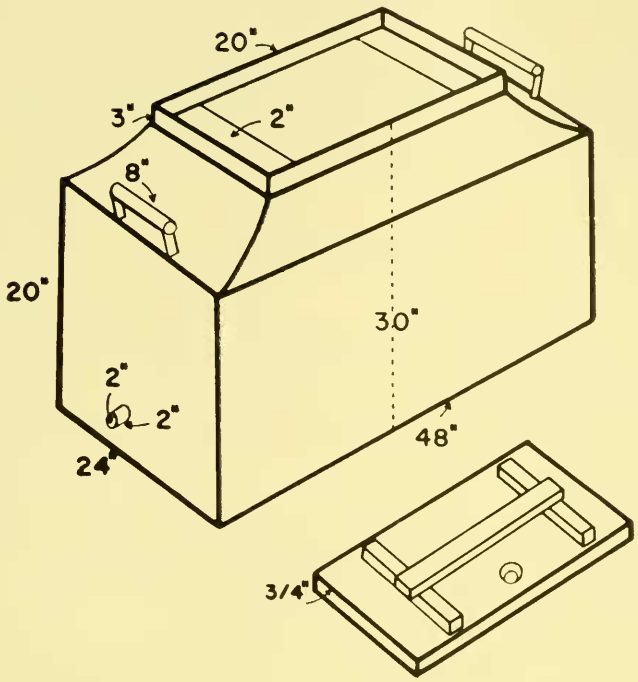

Figure 1. Drawing of a 100-gallon transporting can.

had died; by the end of the third week only 13 fish survived. The fifth shipment of 114 sardines, from Los Angeles harbor, was delivered on October 4, 1950. In 96 hours of confinement in the Aquarium's holding tanks, 54 (47.4 per cent) sardines died off; by the end of the third week the cumulative mortality was 84.2 per cent. On the sixty-second day of captivity only 16 fish survived. The sixth shipment of 116 sardines, from Los Angeles harbor, was received on December 3, 1950. In a 96-hour period 42.2 per cent of the fish died off; at the end of the third week the cumulative mortality was 67.2 per cent. Toward the end of October, 1951 (13 months after delivery), 32 sardines were still living. The seventh shipment of 275 sardines, from Los Angeles harbor, was delivered on October 22, 1951. In a 96-hour period only 38.9 per cent died; at the end of the third week the cumulative mortality was only 42.9 per cent. A count made on January 8, 1953 (14 months and 17 days after delivery), revealed that 43 sardines successfully survived, together with 10 fishes of the sixth shipment.

Maintenance:

At the Steinhart Aquarium, the experimental fish were confined in holding tanks having a capacity of about 1,000 gallons (table I) which, as

our experience indicates, were adequate for about 50 adult fish. The Aquarium salt water is pumped from the ocean to a storage tank and the rate of flow through the 1,000-gallon holding tanks is 86 gallons per hour. Each tank is aërated but in most cases temperature and *p*H are not controlled. In most tanks, the temperature range was 11.0–20.5°C. and that of the *p*H, 7.0–8.0.

Degree of Survival

In transit:

Data on mortality during the sea voyage to San Francisco from Los Angeles were not recorded in the ship's log of the *Yellowfin*. However, according to John Radovich *(in lit.)*, "sardines have been kept alive for an entire cruise on several occasions with a very small loss in the vessel's bait-tank."

From our observations it is readily apparent that sardines of the first load removed from the vessel's bait-tank and transferred to holding tanks of the Aquarium, as a rule, incur heaviest losses during the first three-week period in comparison with those of the other loads of the same shipment that were transferred later. This is especially true of the seventh shipment of October 22, 1951, when 275 sardines were transported in three consecutive truck trips, and distributed in three separate holding tanks at the Aquarium. A very accurate record of mortality was kept, and a summary is presented in table II.

TABLE I

Data on Holding Tanks in Steinhart Aquarium

Capacity	1057 gallons
Inside dimensions	74" x 75" x 44"
Operating water volume	1,000 gallons
Rate of water turnover	86 gal./hr.
Air introduced by suction through opening in water inlet tube	variable rate
Annual temperature range for tank with non-regulated water temperature	11.0°C. to 20.5°C.
Greatest temperature fluctuation in 24 hours	1°C.

Observation indicates that fish of the first load are those which have suffered most during the voyage or from previous handling by the bait-fishermen. They usually swim about close to the surface in the ship's bait-tank and are the first to be netted out for transportation, while healthy fish dive to the bottom of the tank and stay there until netted.

TABLE II

Mortality among sardines of various loads transported in a truck from the Yellowfin *bait-tank to the Steinhart Aquarium holding tanks on October 22, 1951. Shipment consisted of 275 adult sardines.*

Tank number	*Load number*	*Number of fish delivered*	*Number of fish died off*	*Length of mortality period in days*	*Percentage of mortality*		*Remarks*
					Total	*Average daily for mortality period*	
2	1	136	80	6	58.8%	9.8%	No mortality after 6th day until end of 3-week period.
42	2	47					
	3	65					
		112	28	10	25.0%	2.5%	One more fish died between 11th day and end of 3-week period.
41	3	27	5	8	18.5%	2.3%	No mortality after 8th day until end of 3-week period.

Improvements in methods of handling and transporting the fish, such as less crowding and water movement in the truck's transporting cans and the use of artificial light, lowered the mortality significantly (table III and fig. 3). The last three shipments showed a drop in mortality from 84.2 per cent to 42.9 per cent.

In the Aquarium:

The high mortality, as a rule, occurs during the first three weeks of confinement in the Aquarium. In large measure, it reflects the effect of transportation from aboard ship to the Aquarium. In regard to fish survival, these three weeks are considered as a critical period. As our records show, at the end of the first three weeks mortality in the Aquarium holding tanks due to transporting and handling was zero.

Closely comparable results were obtained by Janssen and Alpin (1945). They state that mortality attributable to catching and handling among the sardines kept in floating boxes for tagging experiments was high for about the first six days of confinement (about 55 per cent for the control fish, and 70–75 per cent for the tagged fish). Similarly, after 20 days of confinement there were few deaths.

During the 44-month period, out of the 751 sardines delivered to the Aquarium, 520 fish or 69.2 per cent died during the first three weeks of captivity in the Aquarium. Approximately 178 fish (23.7) per cent from which groups of specimens were drawn for experimental purposes, died thereafter because of accidents, starvation, or other causes of natural mor-

tality, while 53 fish (7.1 per cent) were still living on January 8, 1953 (table VI).

It is shown in table V that only about 44 per cent of the mortality can be attributed to natural causes. Following the critical period, the mortality rate is exceedingly low. For example, of the last or seventh shipment of 275 sardines, 157 survived the critical three-week period after which mortalities were observed on the average (n = 9) at intervals of only 57 days (interval range, 4–109 days). In one instance, 10 sardines survived 768 days but appeared to be starved or suffering from a pathological condition at the end of the experiment.

TABLE III

RECORDS OF SARDINE MORTALITY DURING THE FIRST THREE WEEKS OF CONFINEMENT IN THE STEINHART AQUARIUM'S HOLDING TANKS ATTRIBUTABLE TO TRANSPORTING AND HANDLING*

Last Three Shipments Transported from Los Angeles to San Francisco Aboard the "Yellowfin"

	114 fish delivered on Oct. 4, 1950		*116 fish delivered on Dec. 3, 1950*		*275 fish delivered on Oct. 22, 1951*	
Day	*Daily loss*	*Cumulative percentage*	*Daily loss*	*Cumulative percentage*	*Daily loss*	*Cumulative percentage*
1st	4	3.5	2	1.7	43	15.6
2nd	14	15.8	21	20.0	55	35.6
3rd	20	33.3	18	35.3	8	38.5
4th	16	47.4	8	42.2	1	38.9
5th	12	58.1	13	53.5	1	39.3
6th	10	66.6	7	60.0	1	39.6
7th	6	71.9	5	63.8	3	40.7
8th	4	75.4	2	65.5	2	41.4
9th	3	78.1	1	66.4	2	42.2
10th	3	80.7	0	66.4	1	42.6
11th	2	82.5	1	67.2	0	42.6
12th	1	83.3	0	67.2	0	42.6
13th	1	84.2	0	67.2	0	42.6
14th	0	84.2	0	67.2	0	42.6
15th	0	84.2	0	67.2	0	42.6
16th	0	84.2	0	67.2	0	42.6
17th	0	84.2	0	67.2	1	42.9
18th	0	84.2	0	67.2	0	42.9
19th	0	84.2	0	67.2	0	42.9
20th	0	84.2	0	67.2	0	42.9
21st	0	84.2	0	67.2	0	42.9
Mortality	96	84.2	78	67.2	118	42.9
Survival	18	15.8	38	32.8	157	57.1
Total	114	100.0	116	100.0	275	100.0

*The first shipment from the Los Angeles area which incurred 90 per cent loss at the end of the first three weeks is not included due to incomplete daily recording.

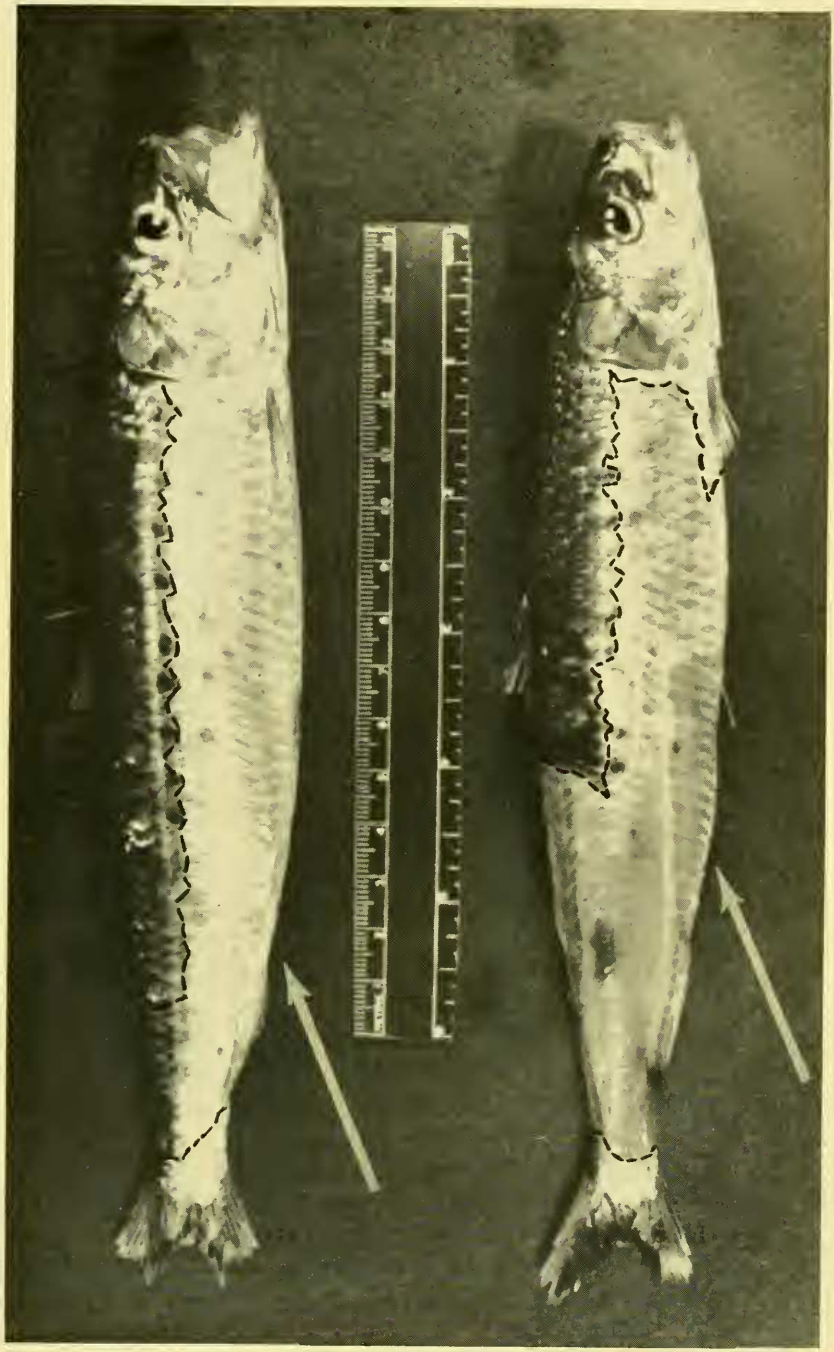

Figure 2. Showing extreme examples of external injury attributable to transporting.

TABLE IV

MORTALITY AND SURVIVAL AMONG SARDINES IN HOLDING TANKS OF THE STEINHART AQUARIUM

Shipment No.	Date of delivery	Number of fish	Mortality due to transporting during first 3 Weeks		Survival of fish of:			Remarks
			Number	Per Cent	Latest shipment (number)	Previous shipment (number)	Total live fish (number)	
1	2	3	4	5	6	7	8	9
1	May 19, 1949	57	57	100.0	0	0	0	
2	August 4, 1949	37	37	100.0	0	0	0	*26 of the
3	December 22, 1949	24	19	80.0	5	0	5	6th ship-
4	June 9, 1950	128	115	90.0	13	5	18	ment and
5	October 4, 1950	114	96	84.2	18	10	28	4 of
6	December 3, 1950	116	78	67.2	38	26	64	the 5th.
7	October 22, 1951	275	118	42.9	157	30*	187	
	Total	751	520	69.2	—	—	—	

Factors Causing Mortality

In Transit:

Examination of the dead fish immediately following delivery has indicated that all of them had lost most of their scales, in some instances, 90 per cent (fig. 2). The first fish to die were those with head or abdominal injuries causing internal hemorrhages of the brain, heart region, or intestinal tract. Fish with badly damaged snout areas and fins survive a little longer, while those with pinpoint subcutaneous hemorrhages over the entire body may live much longer. Fish in the last category with scales intact may even recover and survive the three-week critical period.

When a ship carrying sardines in her bait-tank is preparing to enter a harbor which is fed by fresh water, extreme care should be taken in regard to the time of entrance. From sad experience we know that the rate of mortality is high when the salinity is markedly reduced by the circulation of brackish water through the vessel's bait-tank.

To avoid mortality due to changes in salinity or to pollution, sardine-carrying vessels should enter port at the beginning of flood tide and unload before the ebb. Also, transporting cans to carry the sardines from the docked vessels should contain a fresh supply of sea-water for each truck trip. This is necessary not only because of the salinity factor, but also because of the copious slime secretion and scale shedding, both of which interfere with normal respiration of the fish.

Uninterrupted aëration and a temperature differential not exceeding 3°C. when fish are moved from a vessel to the Aquarium must be maintained to reduce mortality. Also, the use of dip-nets in handling the fish was discouraged in favor of two-gallon buckets with a maximum of four sardines per bucket.

Both external and internal body injuries and extensive shedding of scales result from excessive water motion in the truck cans during transport. When, in 1949, sardines were transported from Monterey Bay to San Francisco, 130 miles in 3.5 hours, it was demonstrated that a single 100-gallon truck can is more satisfactory than four 45-gallon cans.

Mortality in transport was further reduced by providing adequate artificial lighting in the shipping cans so as to reduce mechanical injury of the fish due to contact with the sides of the cans. Overcrowding of buckets and shipping cans is a distinct limiting factor. This study has shown that not more than four adult sardines should be carried in two-gallon buckets, 10 in 45-gallon cans, and not more than 25 in 100-gallon containers.

In the Aquarium:

As stated above, our experience indicates that the number of adult fish in the 1,000-gallon tanks of the Aquarium should not exceed 50. Furthermore, it has been demonstrated that the ill-effects of transportation and

TABLE V

Mortality Due to Causes Other Than Transporting and Handling

Mortality Causes	MORTALITY	
	Number of Fish	Per Cent
Experimental and Accidental:		
A. Exposure to anesthetic test	5	2.8
B. Overexposure to electrical field	25	14.1
C. Removal for physiological examination after hormone injection	19	10.7
D. Leaping from holding tanks	12	6.7
E. Increase of water temperature in summer months, 1949, 1950	39	21.9
Total	100	56.2
Normal:		
F. Starvation	22	12.3
G. Other factors (overfeeding, pathological causes, etc.)	56	31.5
Total	78	43.8
Grand Total	178	100.0

TABLE VI

Sardine Longevity in Confinement

Shipment Number	*Number of Fish Delivered*	*Number of Fish Survived Critical Period*	*Per Cent of Survival After Critical Period*	*Date of Sardine Delivery*	*Latest Date Recorded for Sardine Survival After Critical 3-Week Period*	*Length of Confinement (in days)*
1	57	0	0	May 19, 1949	——	0
2	37	0	0	Aug. 4, 1949	——	0
3	24	5	20.8	Dec. 22, 1949	June 9, 1950	169
4	128	10	7.8	June 9, 1950	Dec. 3, 1950	178
5	114	16	14.0	Oct. 4, 1950	Dec. 3, 1950	60
5	114	4	3.5	Oct. 4, 1950	Oct. 22, 1951	383
6	116	26	22.4	Dec. 3, 1950	Oct. 22, 1951	324
6	116	10	8.6	Dec. 3, 1950	Jan. 8, 1953	768
7	275	43	15.6	Oct. 22, 1951	Jan. 8, 1953	444
7*	275	8	2.9	Oct. 22, 1951	Feb. 1, 1954	832

*The last survivor of the seventh shipment died on May 16, 1954, after having been kept 937 days in captivity.

handling are felt only during the first three weeks following arrival at the Aquarium. During this critical period, the fish either die or become adapted to the artificial environment, and the survivors may be kept for relatively long periods of time (table VI).

Temperature is a critical factor in maintaining sardines under aquarium conditions. In the Aquarium's tanks without temperature control, water temperatures ranged from 11°C. in winter to 20.5°C. in summer. The greatest mortality, presumably due to temperature, occurred during June and July when the temperature rose to above 20°C.

Our experiments suggest that sardines may be safely kept at aquarium temperatures not exceeding 18°C.

These temperature findings are in accord with available information on the temperature conditions under which sardines exist in the sea. The range of water temperatures at which sardine schools were obtained on scouting surveys conducted by the California Department of Fish and Game was from 11°C. to 20.4°C. (California Cooperative Sardine Research Program, 1951). Daniel Miller* concludes on a basis of field records that "from the general picture it would seem that sardines might prefer temperatures in the range of from 13 C. to 18°C. It must be remembered, however, that these data were collected in all months of the year and within the entire

*Scripps Institution of Oceanography, Report on the 1952 Sardine Conference, page 5, October 30, 1952 (mimeographed).

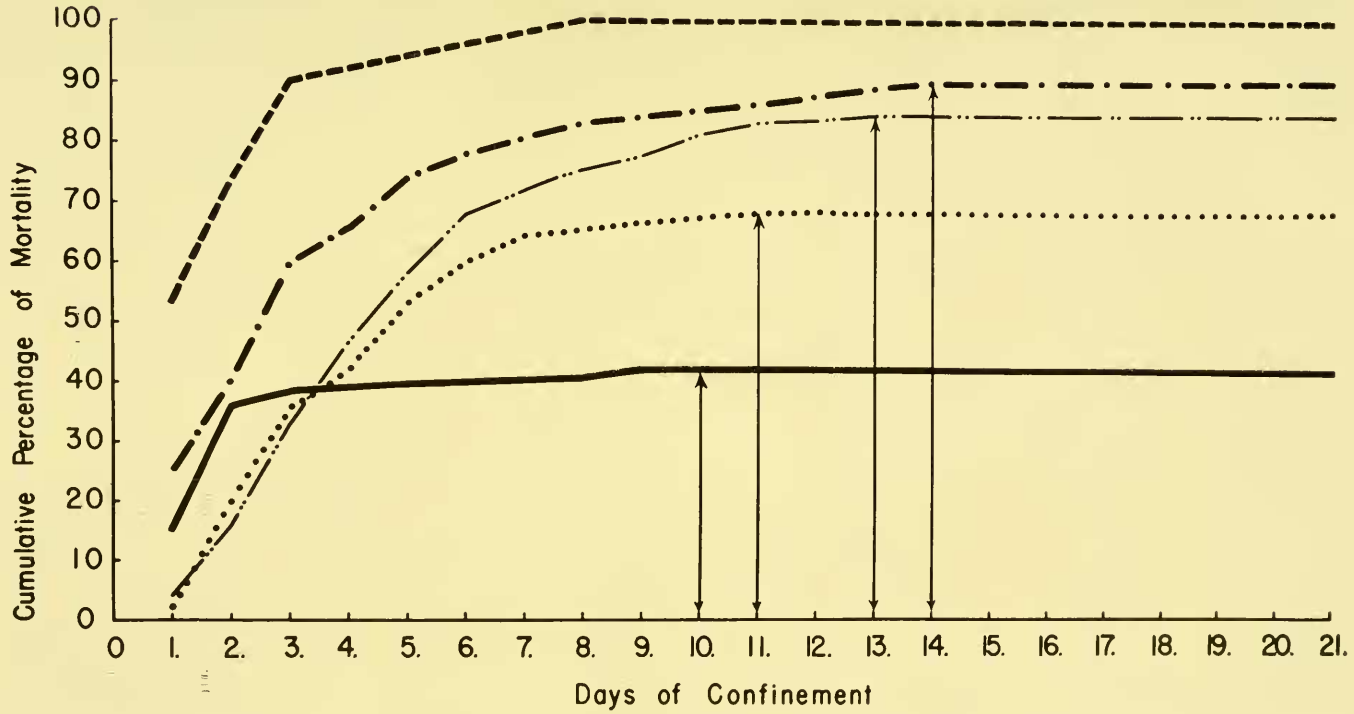

Figure 3. Cumulative percentages of sardine mortality attributable to transporting and handling during the first three weeks of confinement in 1,000-gallon holding tanks at Steinhart Aquarium. - - - - first and second Monterey shipments; - - - - - first shipment from the Los Angeles area; - - - - - - second shipment from the Los Angeles area; . . . . . third shipment from the Los Angeles area; and _____ fourth shipment from the Los Angeles area.

area surveyed off our coast." Schmidt (1936), who studied the iwassi, a Japanese sardine, *Sardinops sagax melanostictus,* states, "Iwassi is very sensitive to temperature and it prefers to keep to regions where the temperature of the surface water is between 12° and 19° C. The sardines begin to advance to our shores in the Peter the Great Bay when water is warmed to a temperature of 8°–10°C., which is usually by the end of May, or in the beginning of June. When water temperatures have reached 12°C., the catches of sardines become abundant. With the increase of water temperature up to 18°–19°C., the sardines move northward in search of cooler water." Suehiro (1951) experimented on the tolerance of the Japanese sardine to sudden temperature changes. He writes, "when sardines which at the time of the experiment were living in sea water of about 22°C. were transferred directly into an experimental tank having a water temperature of 28°C. there was only 10–15% mortality in the course of three hours." When fish from normal temperature water were transferred directly to water with 30°C., "there was within 1 hour and 30 minutes a mortality of 60–100 per cent, a result almost equivalent to total destruction."

During our studies, the *hydrogen ion concentration* of the circulating water in the holding tanks varied from 7.0 to 8.0 *p*H values. Tests on eight adult sardines, 200 mm. in standard length, showed that a *p*H of 6.0 may be tolerated for 24 hours without visible harm.

Artificial light in the transporting cans has been found to reduce mortality. John Radovitch *(in lit.)* states that "A night light is necessary to keep the fish milling instead of smashing into the sides of the tank. A surprisingly large number of fish may be confined in a tank if the tank is large enough to allow the fish to mill in a circle." In the Aquarium, it is not necessary to keep the tanks lighted at night after the critical three-week period. By then, the fish have become sufficiently adjusted to the space factor to avoid injuring themselves against the walls of the tank.

Regarding the *food* of the sardine, Blin (1923), De Buen (1927), and Parr (1930; commenting on a paper by Lewis 1929), stress the importance of copepods. Dr. Cadet Hand* found that 30.8 mg. of organic matter consisting of seven groups—diatoms, dinoflagellates, small copepods, large copepods, euphausiids, chaetognaths, and fish eggs—constitutes an average stomach content for the Pacific sardine. Significantly, the copepods comprised 25.7 mg. or 83.7 per cent of the total weight. Copepods not being readily available, the brine-shrimp, *Artemia salina* was used for food, and it proved to be ideal. For a long period sardines rejected other foods used for different fishes of the Steinhart Aquarium, but after confinement of over a year they readily consumed finely chopped or ground horse heart, fish, and even commercially manufactured dry fish pellets containing protein.

*Scripps Institution of Oceanography, Report on the 1952 Sardine Conference, p. 18, October 30, 1952 (mimeographed).

Interestingly, sardines coexist in the Aquarium's tanks with other kinds of fishes, such as grunts, *Brachydeuterus axillaris;* bonefish, *Albula vulpes;* starry flounders, *Platichthys stellatus;* lingcod, *Opiodon elongatus;* staghorn sculpins, *Leptocottus armatus;* and buffalo sculpins, *Enophrys bison.* Usually, the sardines occupy the upper, and the remaining species the lower water layers of the tanks. No intermingling of the two groups has been observed.

In conclusion, this study has shown that, despite its delicate physical structure and high sensitivity to handling, the Pacific sardine may be satisfactorily maintained under aquarium conditions, and that it may, therefore, be subjected to experimental investigations.

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LITERATURE CITED

ALLEN, W. E.

1920. Behavior of loon and sardines. *Ecology,* 1:309–310.

1930. Elusive sardines. *Catalina Islander,* 17(4):10.

BLIN

1923. Note sur l'alimentation de la sardine: *Euterpes* et sardines. *Societé Zoologique de France, Bulletin* 48(2–3); 99–105, 4 figs.

BREDER, C. M. JR.

1929. Certain effects in the habits of schooling fishes as based on the observations of *Jenkinsia. American Museum Noritates,* 382:1–5.

BUEN, FERNANDO DE

1927. Notes preliminares sobre la biologia de la sardine. *Instituto español de Oceangrafia, Notas y resumenes,* ser. 2, no. 15, 55 pp., 7 figs.

California Cooperative Sardine Research Program
1950. Progress Report, 1950, p. 45.

Cornish, Thomas
1883. Habits of the pilchard. *Zoologist*, London, ser. 3,7:505–506.

Hubbs, Carl L.
1948. "Leapfrogging" by topsmelt and shark. *Copeia*, 4:298.

Janssen, Jr., John F., and J. Alfred Alpin
1945. The Effect of Internal Tags Upon Sardines. *California Fish and Game, Fish Bulletin*, 61:43–62.

Lewis, R. C.
1929. The food habits of the California sardine in relation to seasonal distribution and microplankton. *Bulletin of Scripps Institution of Oceanography, Technical Series*, 2(3):155–180, 2 figs.

Newman, E.
1876. Mr. Saville Kent's lecture, at the Society of Arts, on "The Aquarium: construction and management." *Zoologist*, London, ser. II, 11:4853–4858.

Parr, A. E.
1927. A contribution to the theoretical analysis of the schooling behavior of fishes. *Occasional Papers of the Bingham Oceanographic Foundation*, 1:1–32, 3 figs.
1930. Is the presence of phytoplankton in the stomach contents of California sardine caused by special pursuit or merely due to incidental ingestion? *Ecology*, 11(2):465–468.

Powers, Edwin B.
1921. Experiments and observations on the behavior of marine fishes toward the hydrogen-ion concentration of the sea water in relation to their migratory movements and habitat. *Publications of the Puget Sound Biological Station* 3:1–22, 4 pls.

Schmidt, P. J.
1936. Migration of fishes, First Edition, Moscow-Leningrad, pp. 90–96 (on Japanese sardine), in Russian.

Shelford, V. E., and E. B. Powers
1915. An experimental study of the movements of herring and other fishes. *Biological Bulletin*, 28:315–334, 1 fig., 2 charts.

Shlaifer, A.
1941. Additional social and physiological aspects of respiratory behavior in small tarpon. *Zoologica*, 26:55–60.

Shlaifer, A., and C. M. Breder, Jr.
1940. Social and respiratory behavior of small tarpon. *Zoologica*, 25:493–512, 2 pls., 1 fig.

SPOONER, G. M.

1931. Some observations on schooling in fish. *Journal of Marine Biological Association of the United Kingdom*, new series, 17(2):421–448, 12 figs.

SUEHIRO, YASUO

1951. A study of the causes of death of bait fishes. Translated from the Japanese language by W. G. Van Campen. Washington, D.C., U.S. Fish and Wildlife Service. *Special Scientific Report: Fisheries* no. 62, 57 pp., 1 pl., 15 figs.